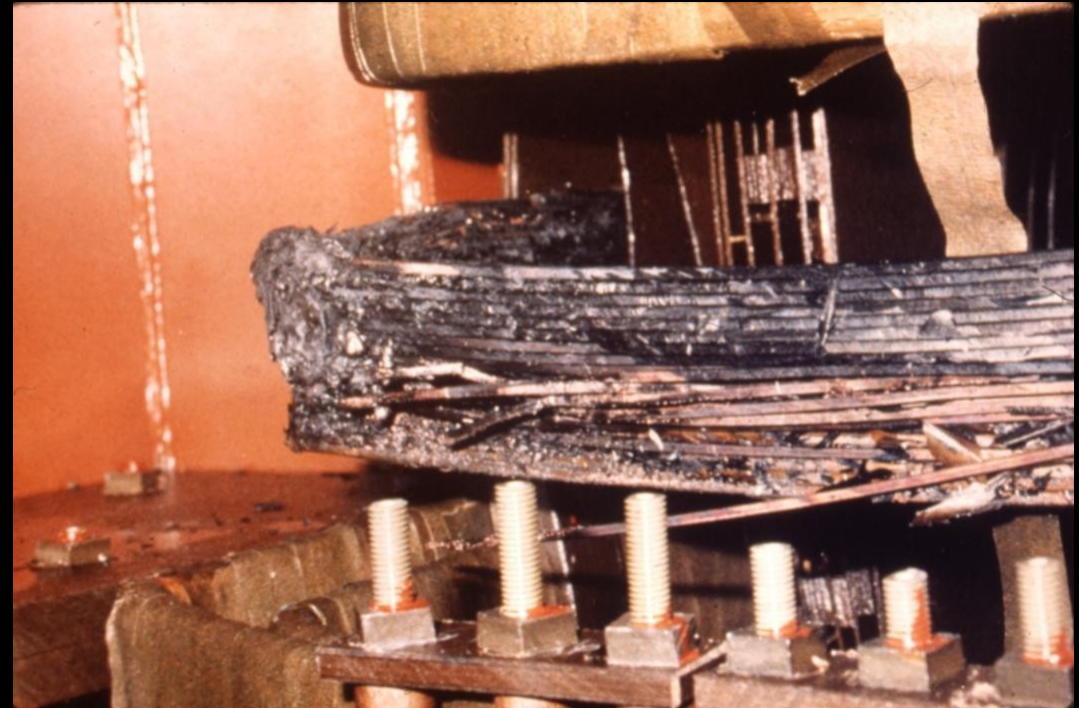


In 1989, A Massive Blackout Left Millions
without Power for Twelve Hours

Image from a NASA Artist's Concept



Transformer Damaged from Geomagnetically Induced Current (GIC)



Images Provided by J.G. Kappenman, used with permission

Short-wave Radio Communications Affected

Jammed radio signals into Russia from Radio Free



Audio is provided with permission from amateur radio astronomer, Radio Jove participant,
and
NASA Citizen Scientist Thomas Ashcraft.

Auroral Oval Moved South (North) Toward the Equator, Aurorae Seen in Fl



Jan 20, 2016: Image taken from the International Space Station (ISS) by NASA astronaut Scott Kelly and European Space Agency (ESA) astronaut Tim Peake. Lights from the Pacific Northwest are seen below the Aurorae.

What Caused these Problems?
i.e., Power Outage, Short-Wave Fade
Aurorae Seen far to South (or North)

Could it be:

Earthquakes?

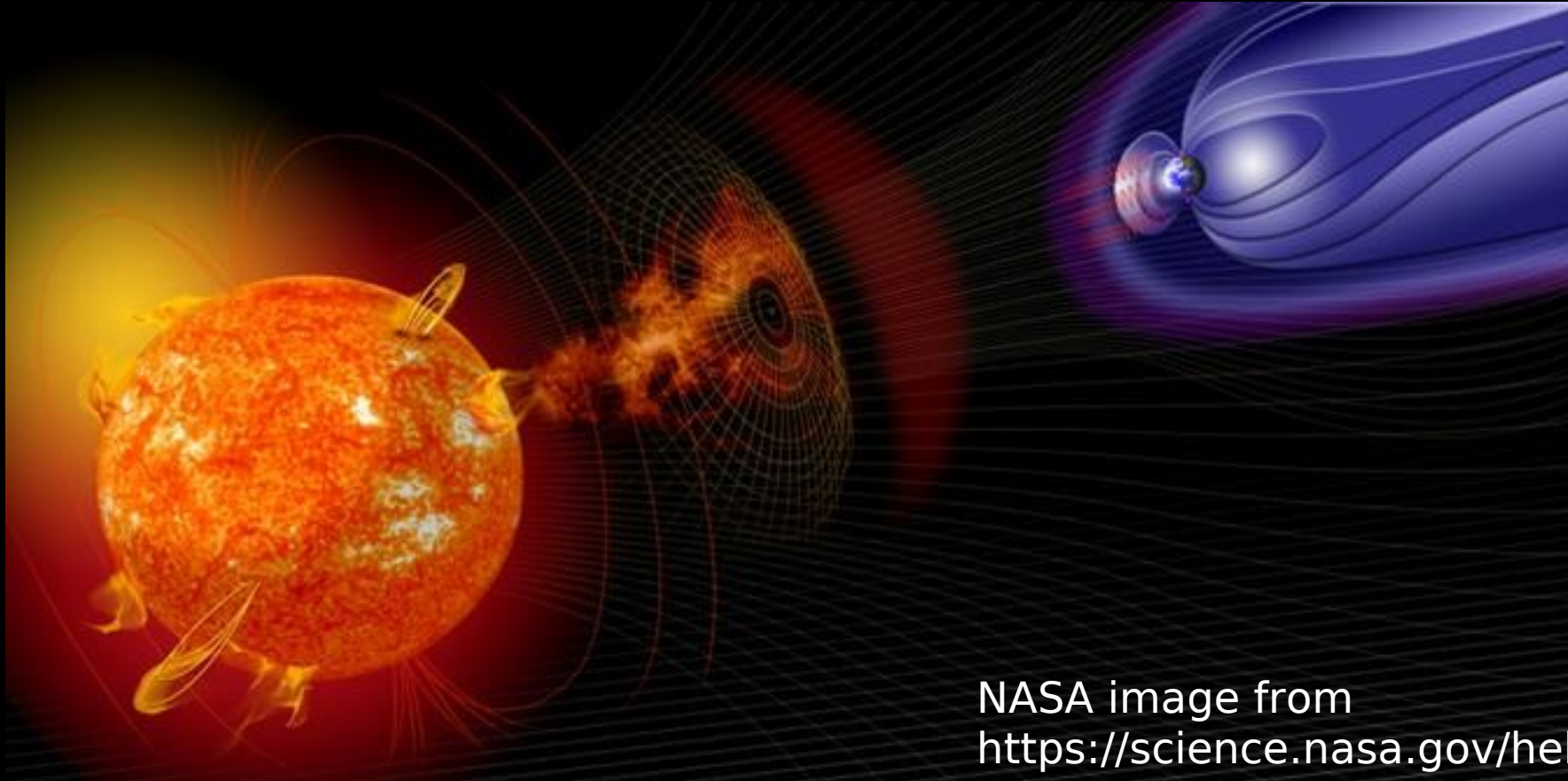
Tornadoes?

Hurricanes?

Alien Invasion?

The Answer Is ---

Space Weather!



NASA image from
[https://science.nasa.gov/heliophysics/space-](https://science.nasa.gov/heliophysics/space-weather/)

The Sun, Solar Cycle 25, and the Tale of Two Eclipses

Mitzi Adams and Adam Kobelski
Solar Scientists

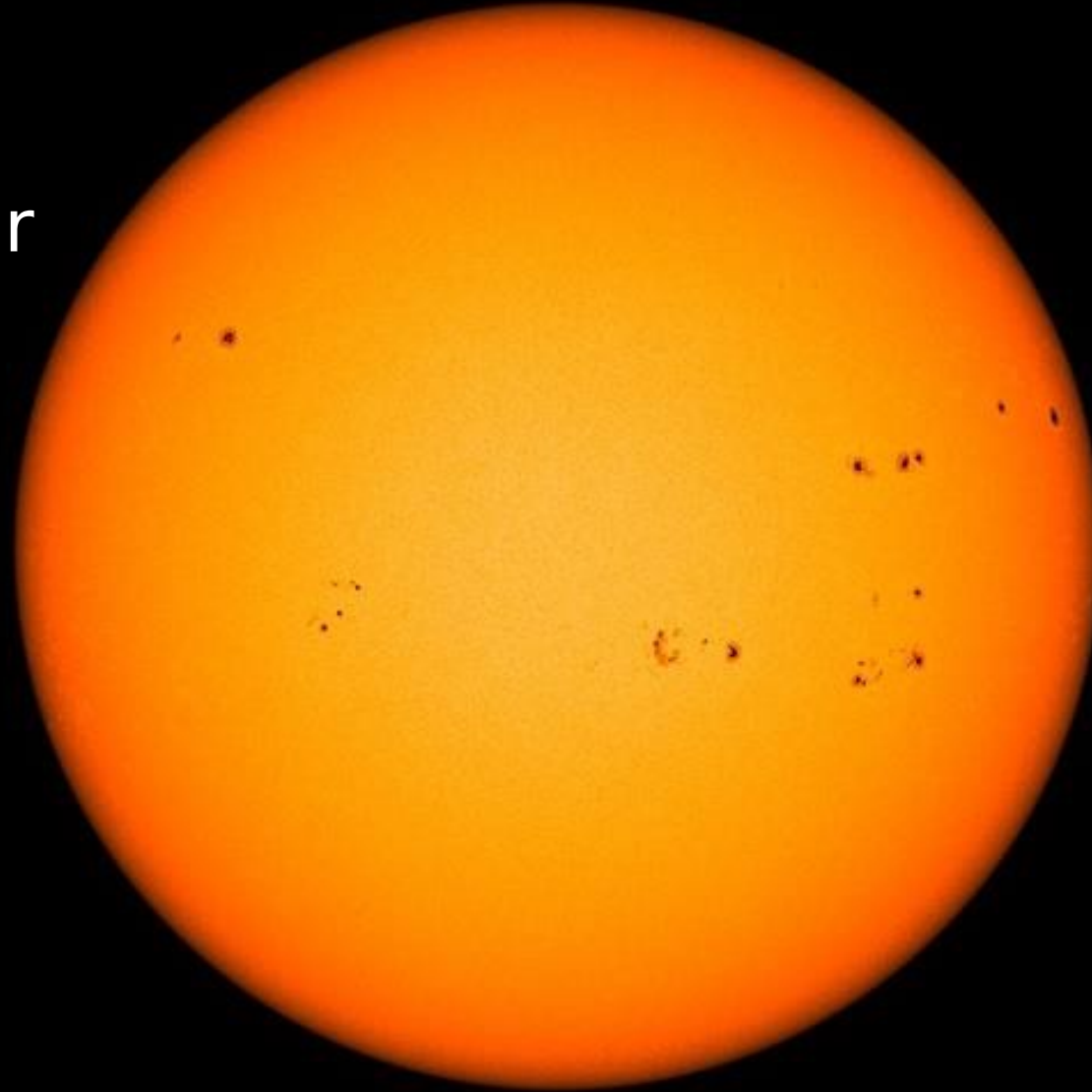
NASA/Marshall Space Flight Center
February 23, 2023

Background image from NASA's
Scientific Visualization Studio

What We See on the Sun, our Closest Sta

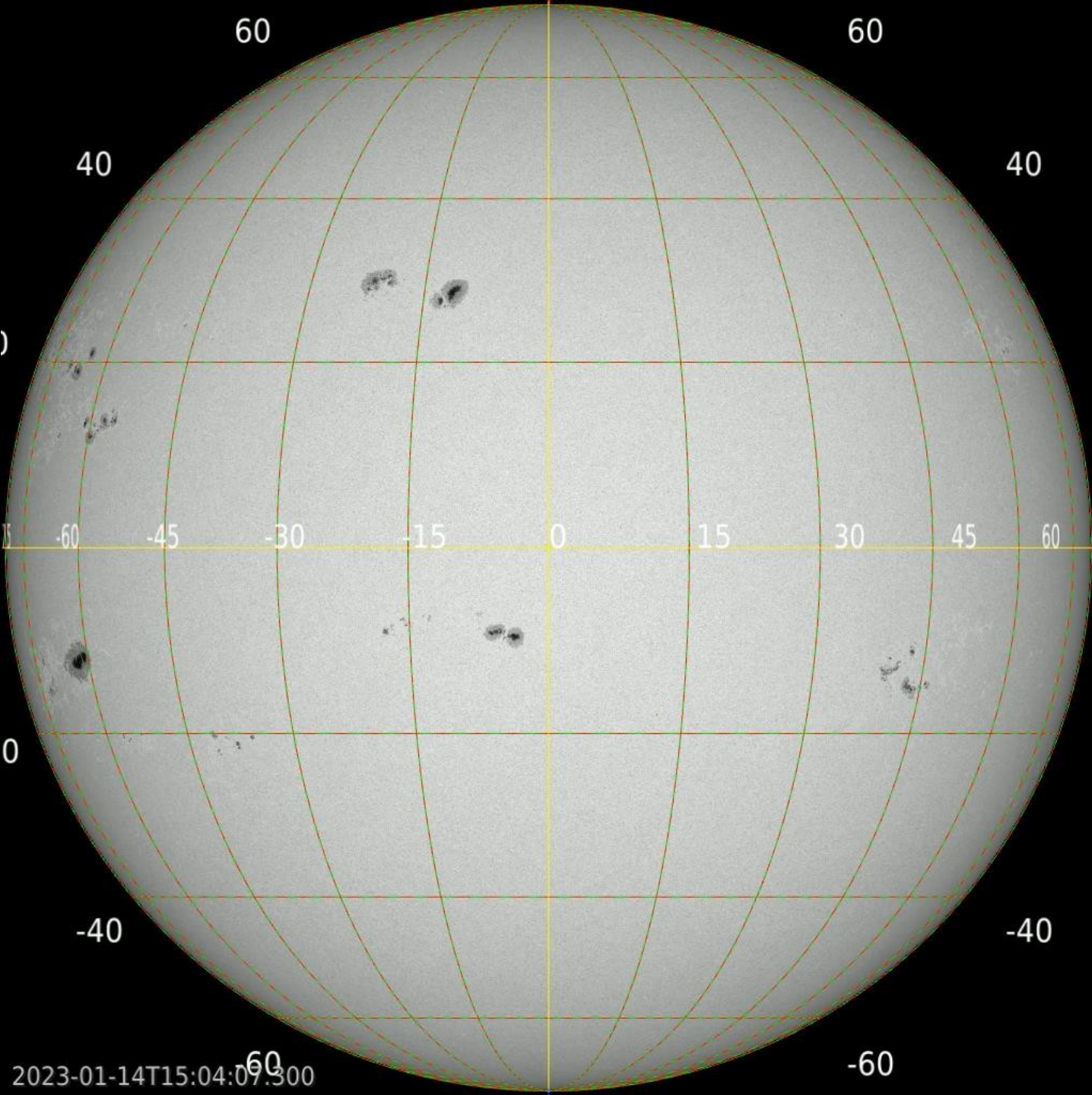
The Sun is a Star

The Sun produces light all “colors” of the EM spectrum:
γ rays, X rays, UV, visible, IR, μwave, radio.



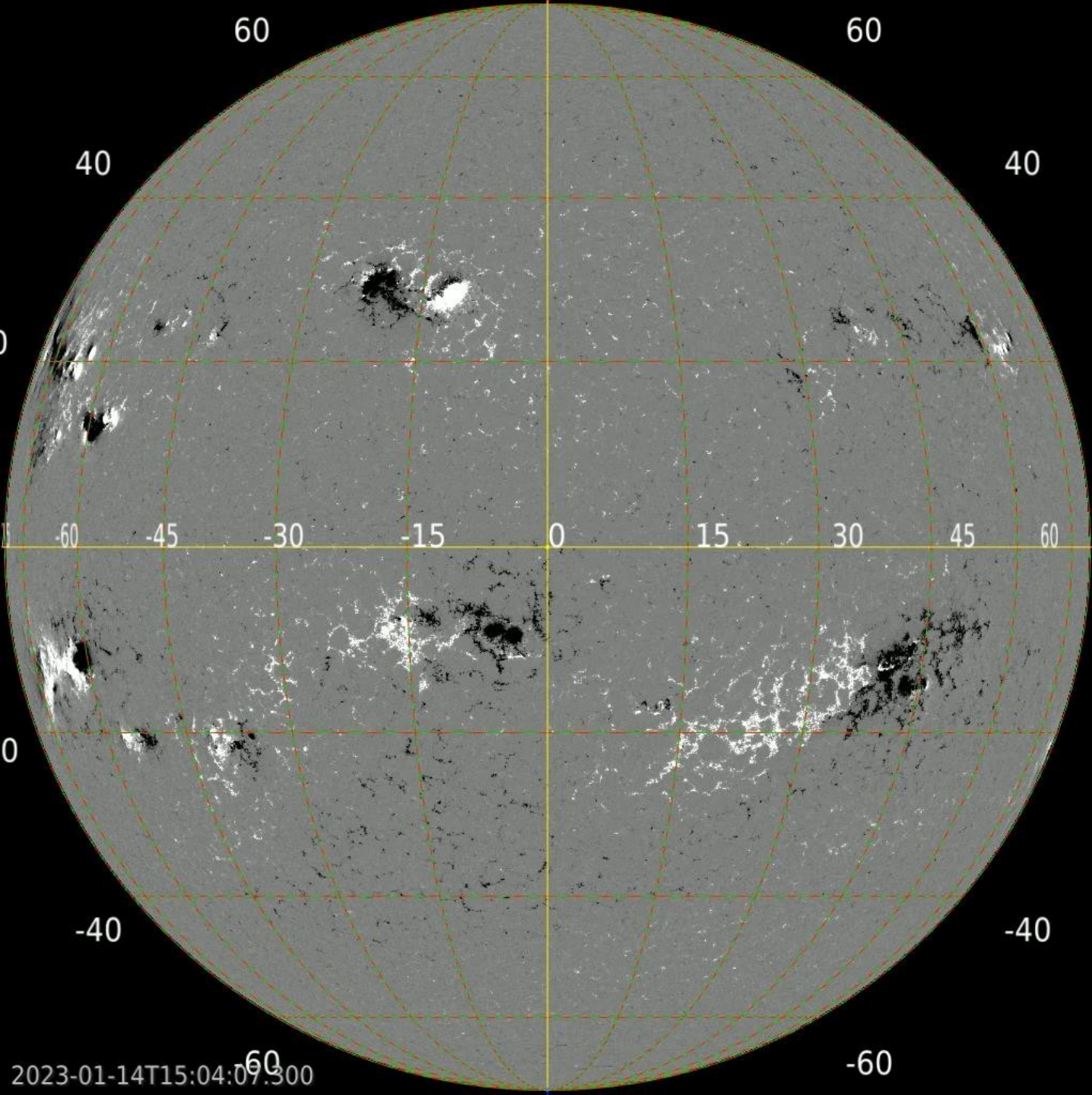
The Sun produces “wind” of charged particles, electron and protons, which flows steadily all the time.

The Photosphere — with Sunspots!



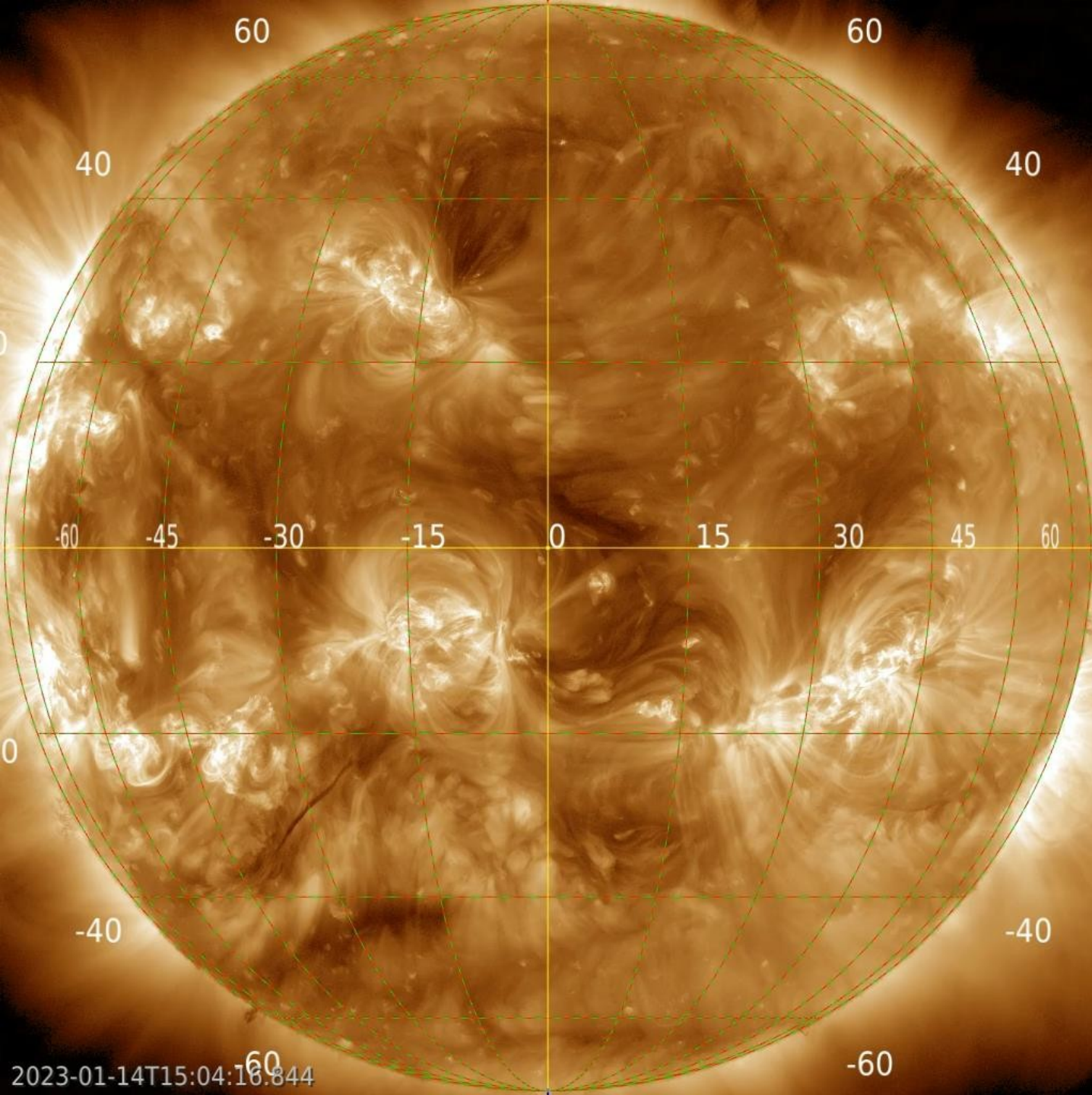
This Recent Image from the
Solar Dynamics Observatory
Shows Sunspots

The unspotted area is about
6000 K (10,000 F), sunspots
are about 3700 K (6200 F)
the darkest part of the
Sunspot (Umbra)



This Image, also from the Solar Dynamics Observatory, shows the Magnetic Field that is associated with the Sunspots.

Sunspots are Cooler than the surroundings since the Magnetic Field holds back Hot plasma from below.



This Image, also from the
Solar Dynamics Observatory
shows the Corona over the
period

The hot (~ 1.8 Million $^{\circ}\text{F}$!) plasma
traces magnetic field lines
sunspots

Due to 'differential rotation', the equatorial region rotates about once every ~ 25 days, the poles closer to ~ 35 days

This rotation drags the magnetic field with it, causing the 'solar cycle'



Sunspot Cycles Since ~1610

What Happened in 1610?

Galileo Galilei and Thomas Harriot observed sunspots through a telescope.
Johannes and David Fabricius and Christoph Scheiner made observations.
Johannes Fabricius published about sunspots later in 1611.

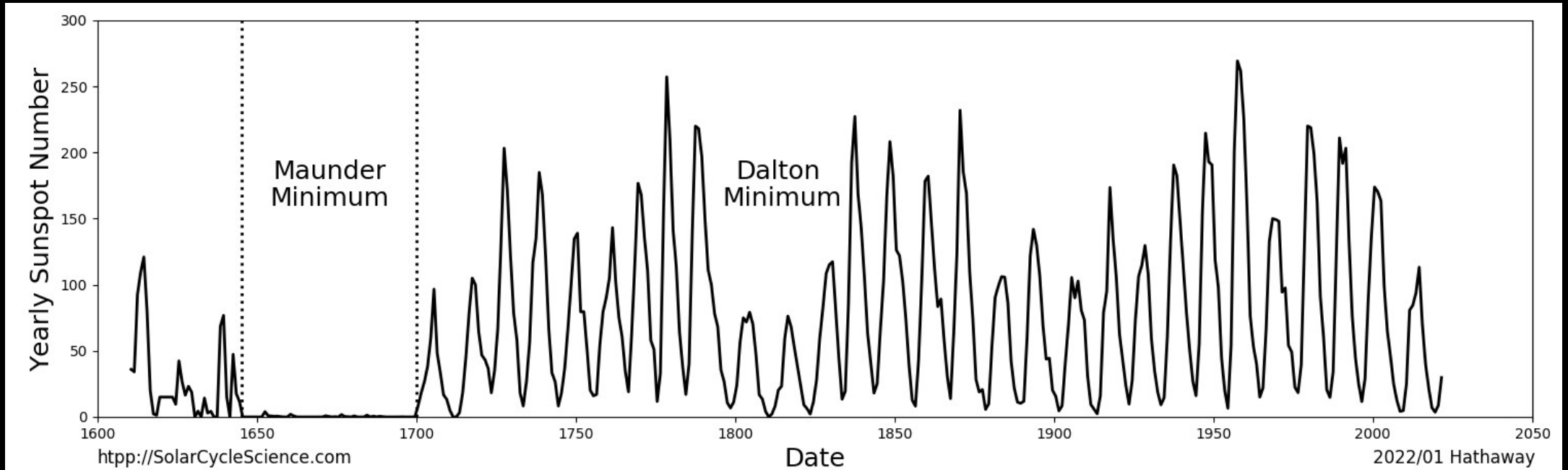
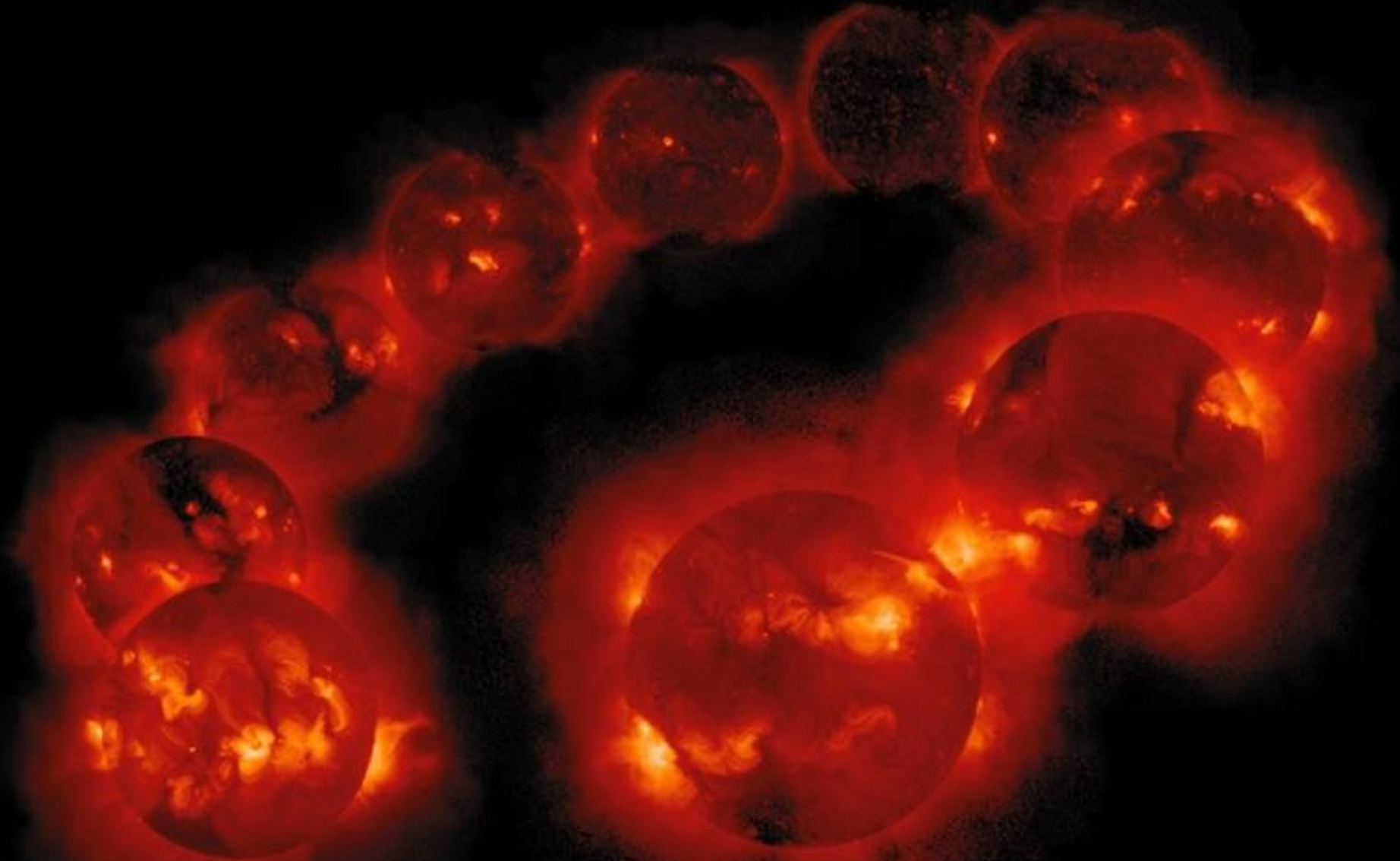


Image Used with Permission from Dr. David Hathaway



The Appearance of Sunspots Follows an Eleven-Year

Sunspot Cycle

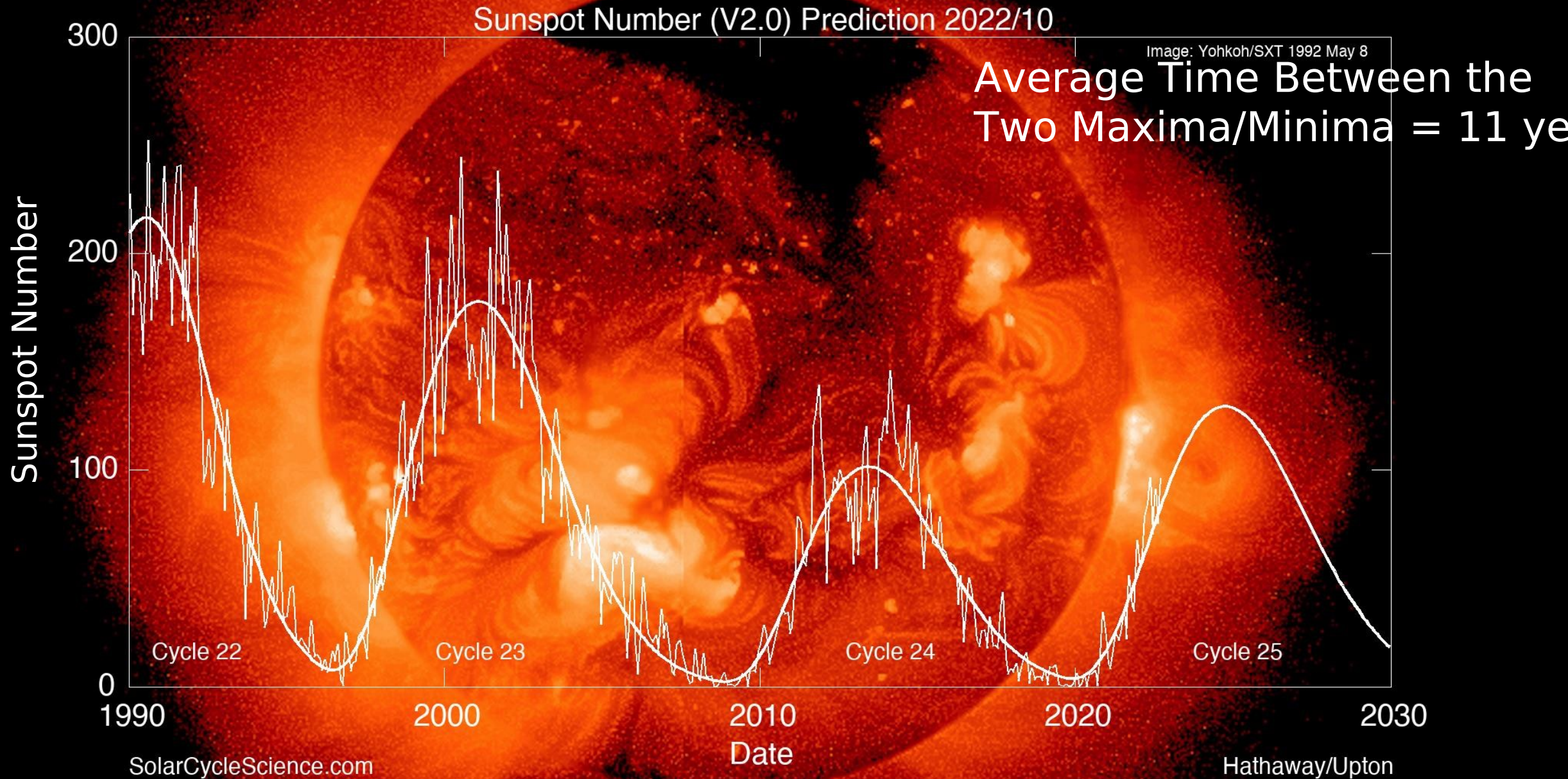


Image Used with Permission from Dr. David Hathaway

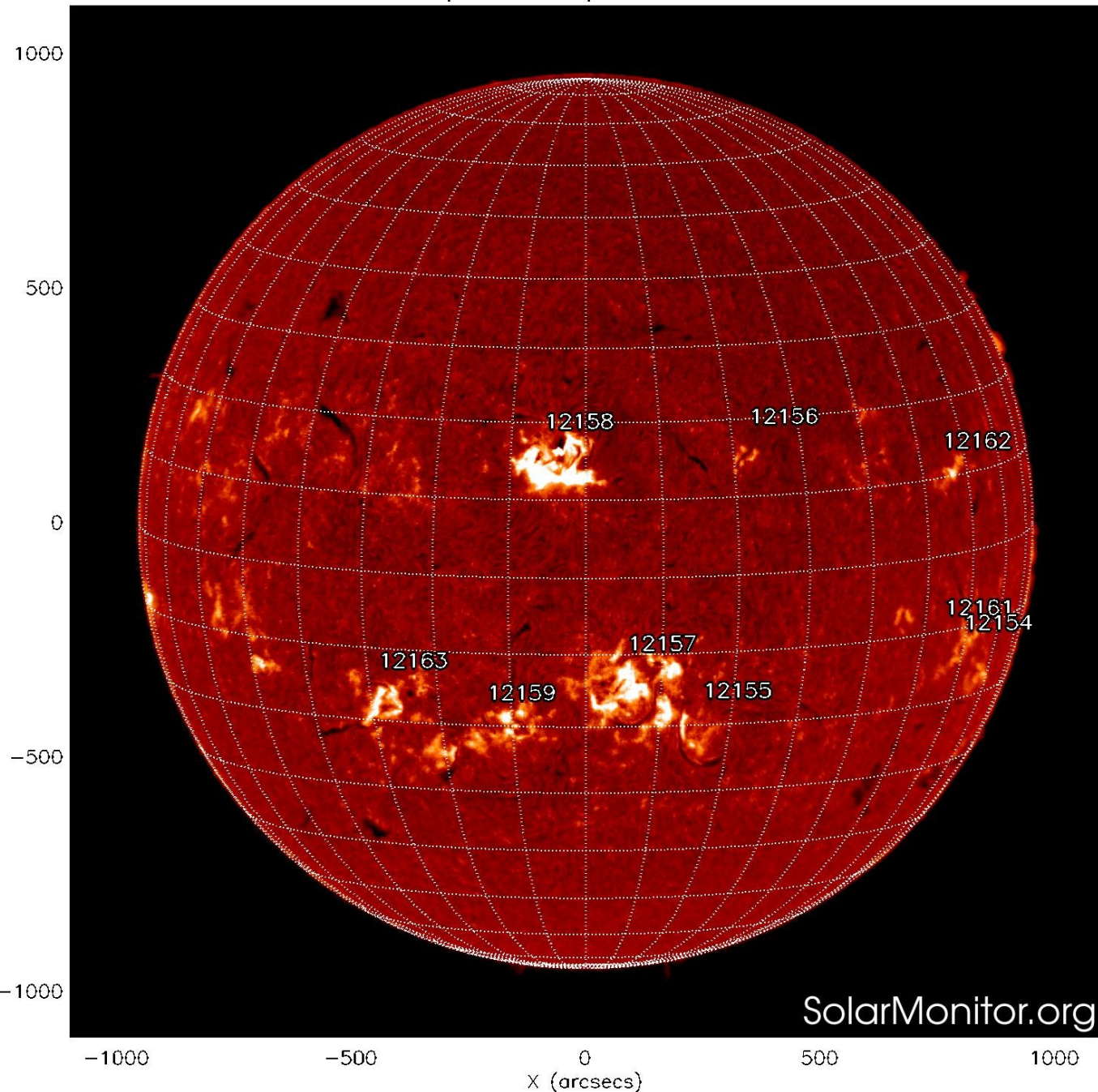
The minimum of Solar Cycle 24 and the beginning of Cycle 25 was in December 2019.

Maximum is predicted to be on or after January 2022.
Simple Methods for Predicting the Size and Timing of Sunspot Cycle 25, Robert M. Wilson, Journal of the Royal Society (Academy of Science).

Okay, so we have graphed the number of suns
(accurately) since the mid 1850s and made predict
Solar Cycle 25.

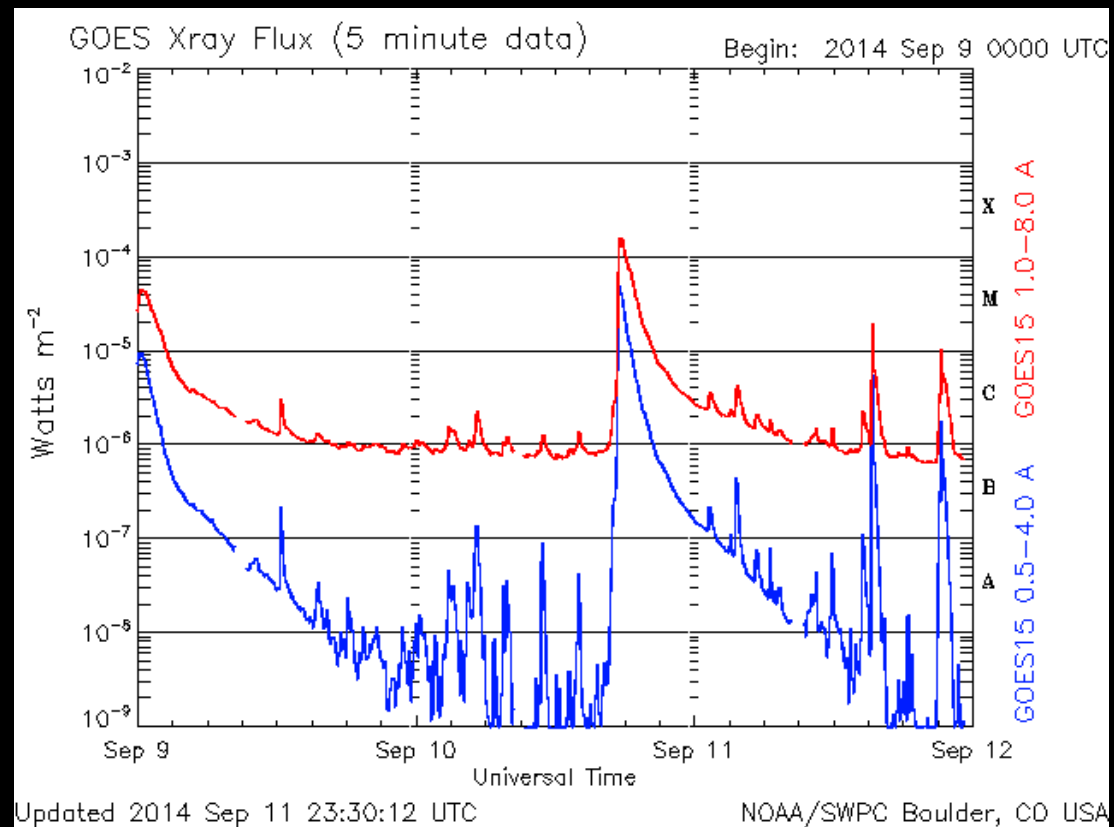
So what?

BBSO H-alpha 10-Sep-2014 19:31:00.000

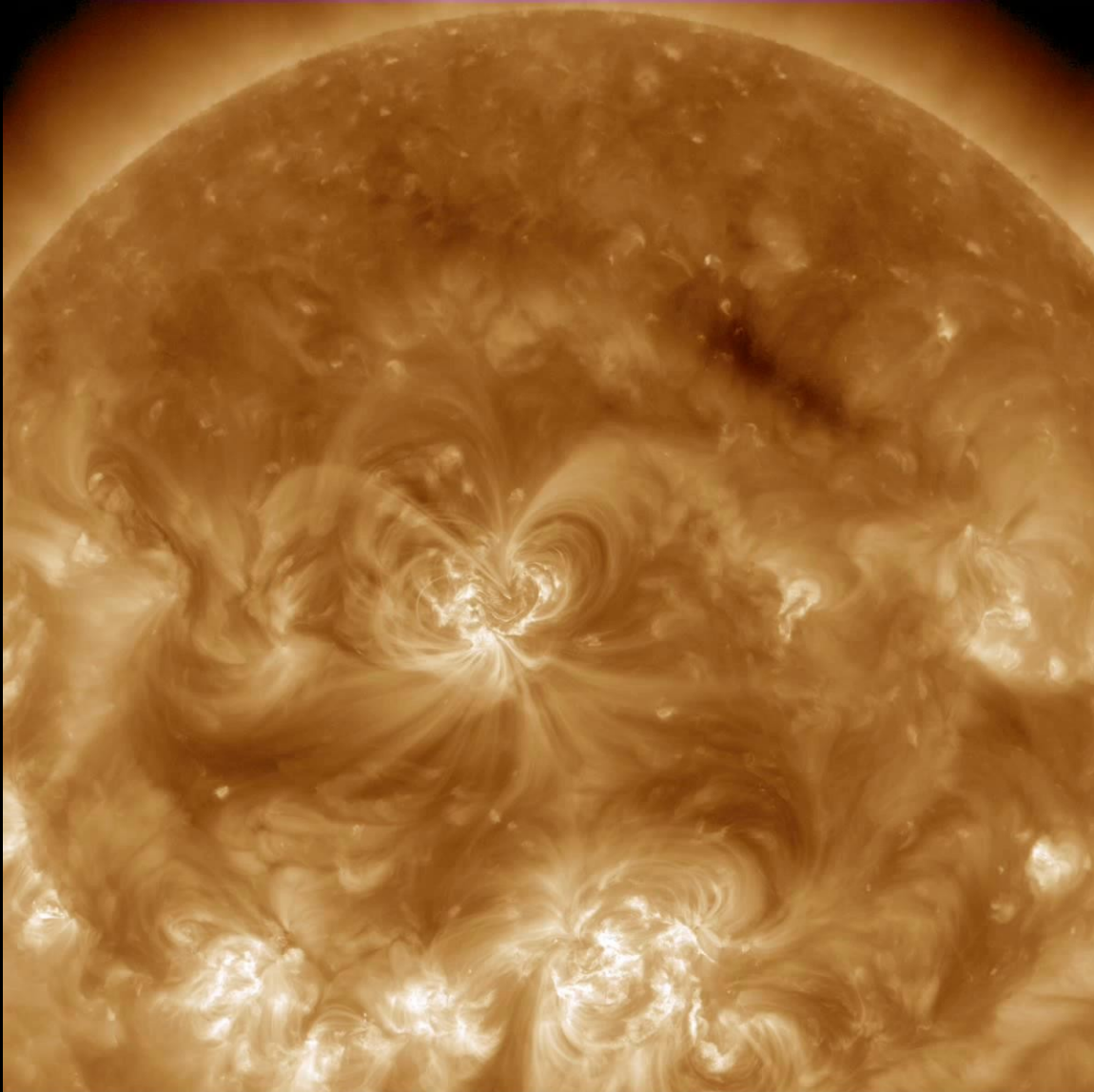


Active Region (AR) 12158 produced a X1.6 flare

[Solar Cycle 24 reached maximum in April 2014]



Flare, as Seen from the Solar Dynamics Ob in Extreme Ultraviolet Light



Flares, such as this one, can create
Coronal Mass Ejections (CMEs) that
impact objects in the heliosphere

-> Space Weather

Let's Summarize So Far

The Sun is a star that produces many “colors” of light: γ rays, X rays, UV, visible, IR, μ wave, radio.

The Sun produces spots on its “surface” (photosphere), darker and cooler than the surrounding unspotted area.

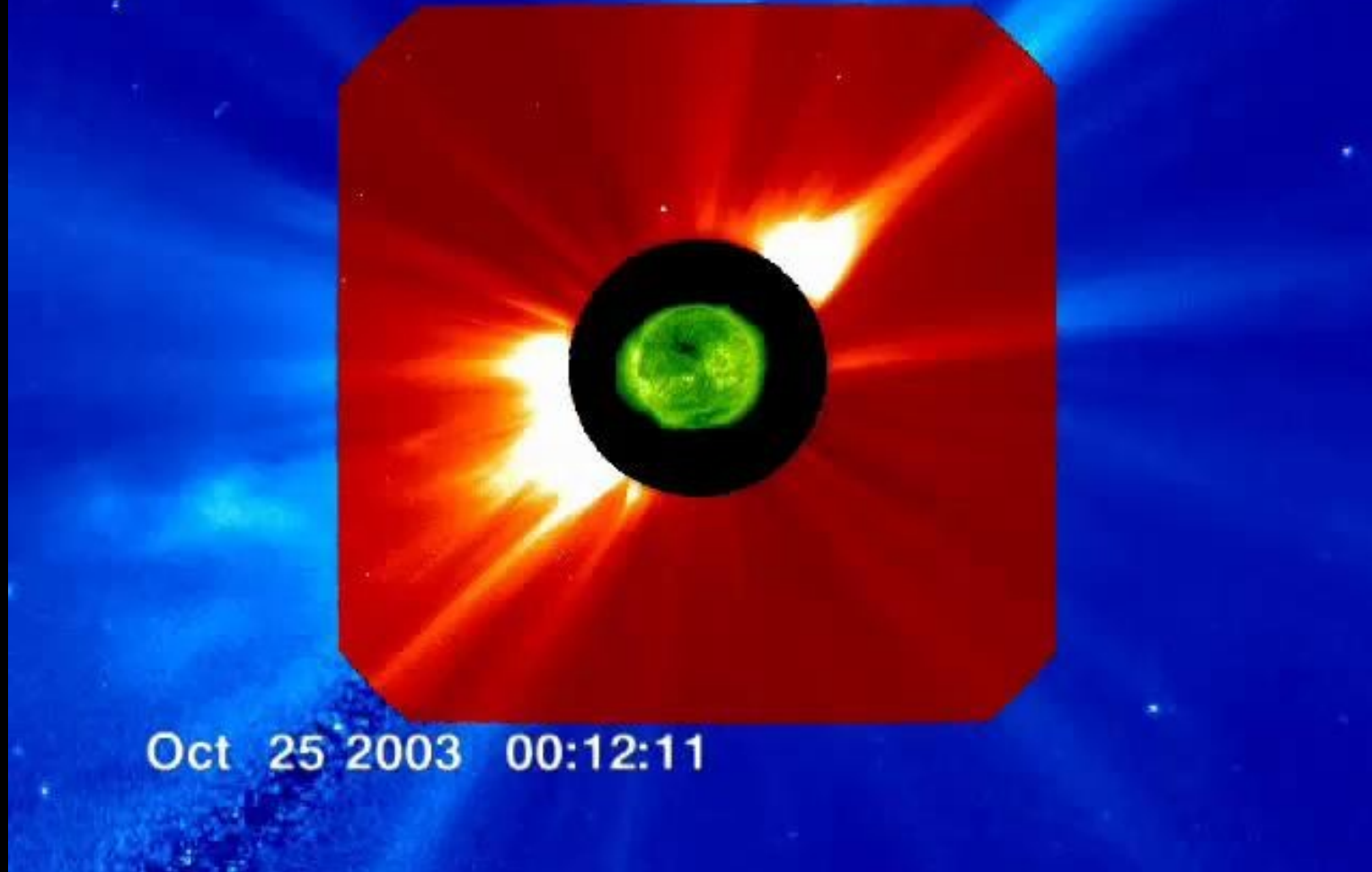
These sunspots appear and disappear cyclically, the Sun's activity follows an 11-year cycle with approximately eleven years between maxima or minima.

The Sun produces bursts of energy called flares. We measure their intensity with a satellite that detects X rays. The brightest flares are called M-class flares.

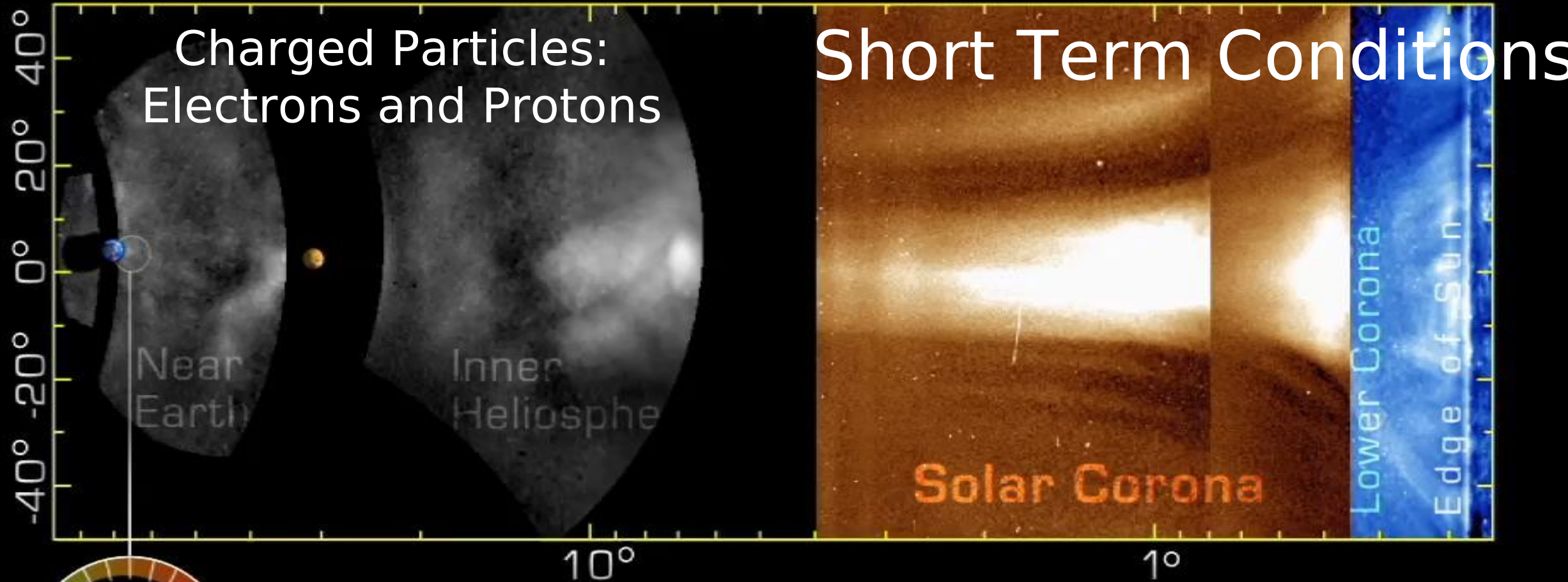
Flares and Coronal Mass Ejections give rise to Space Weather.

The “Halloween Events”

SOHO Extreme Ultraviolet Imaging Telescope (EIT)
at 195 Angstroms, on SOHO Large Angle and
Spectroscopic Coronagraph (LASCO) images



What is SPACE Weather?

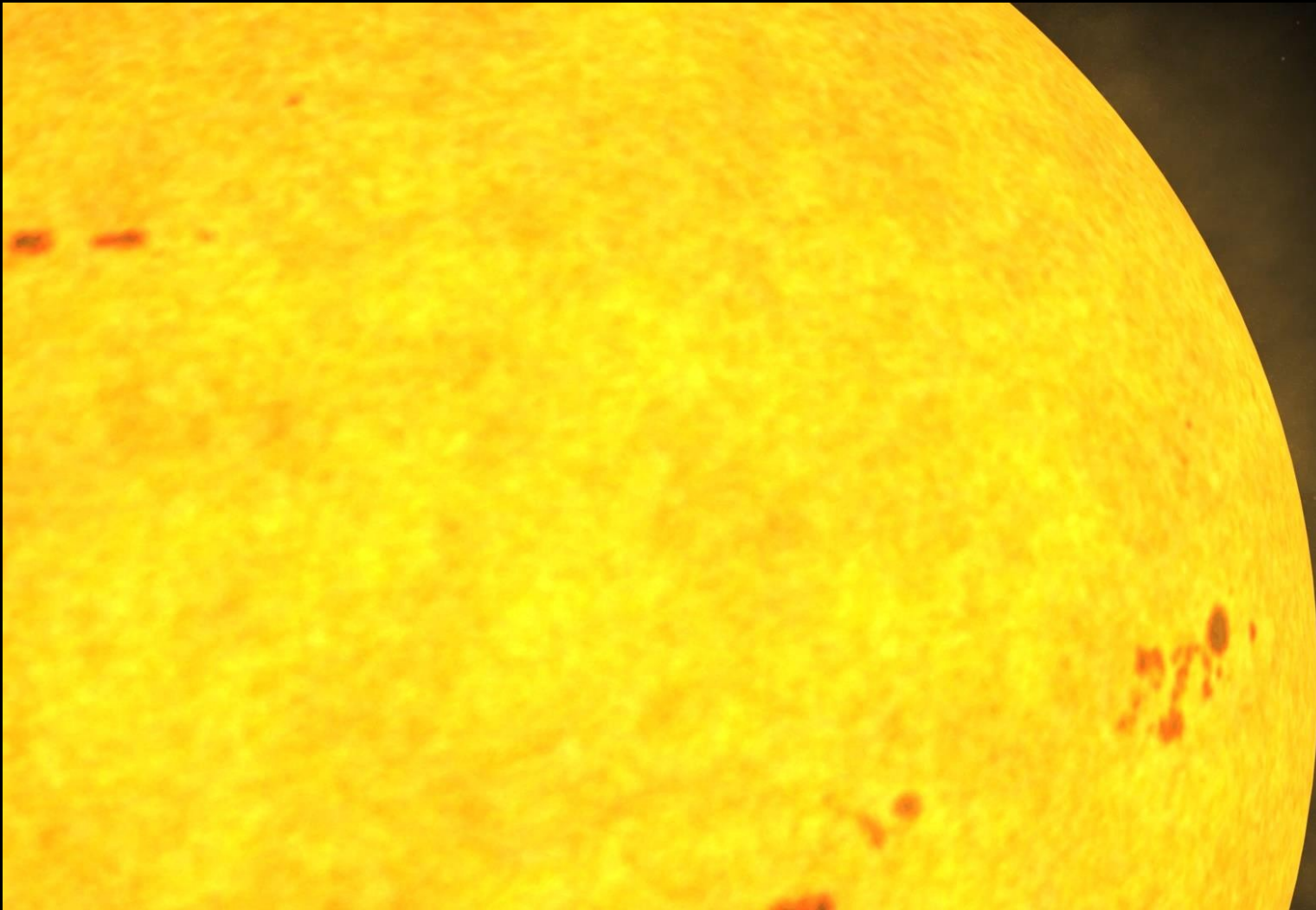


“Windy”

STEREO-A: 12/11/08 12:40:00 AM

Animation from <https://svs.gsfc.nasa.gov/10809>
Credit: NASA/Goddard Space Flight Center/SwRI/STEREO/WIND

Space Weather: From Sun to Earth

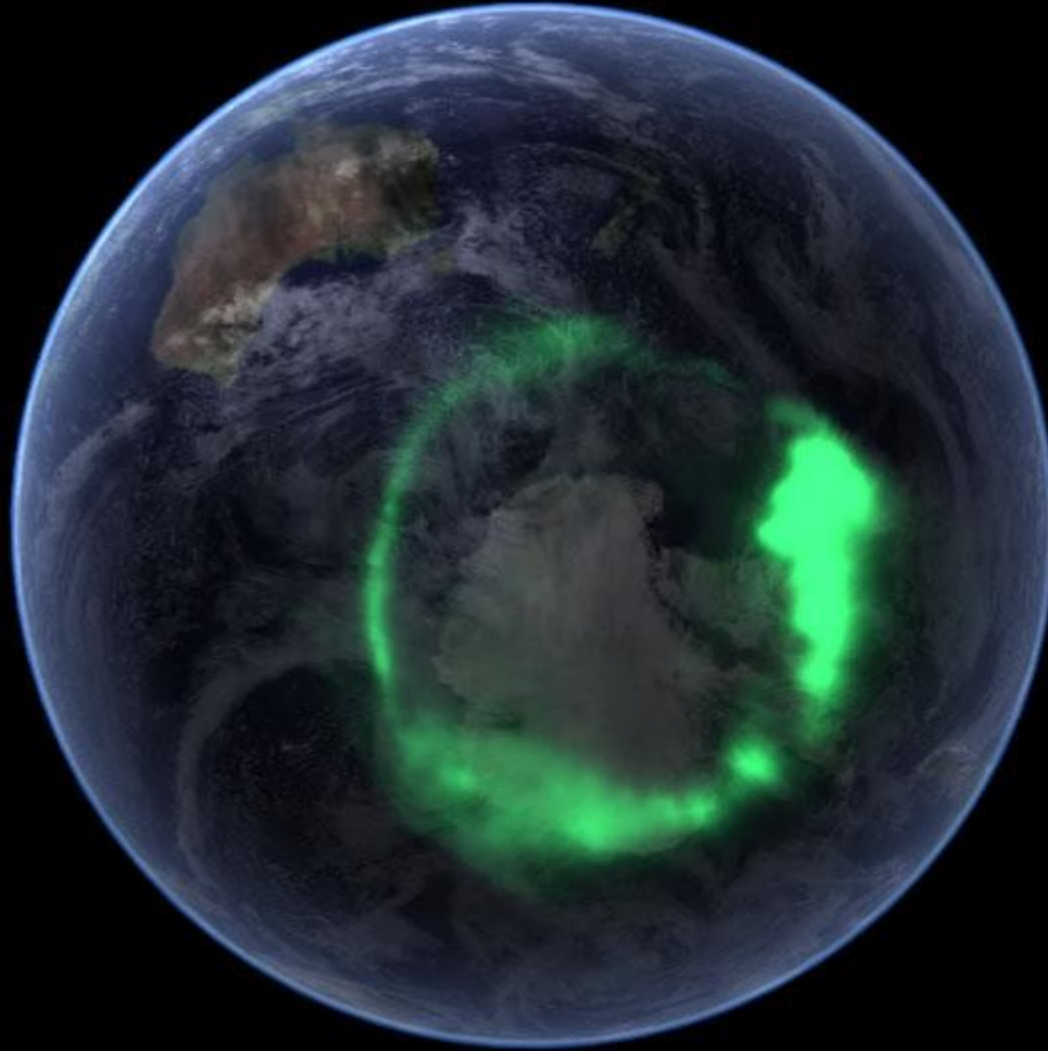


Magnetic
Reconnection
At the Sun
and Earth

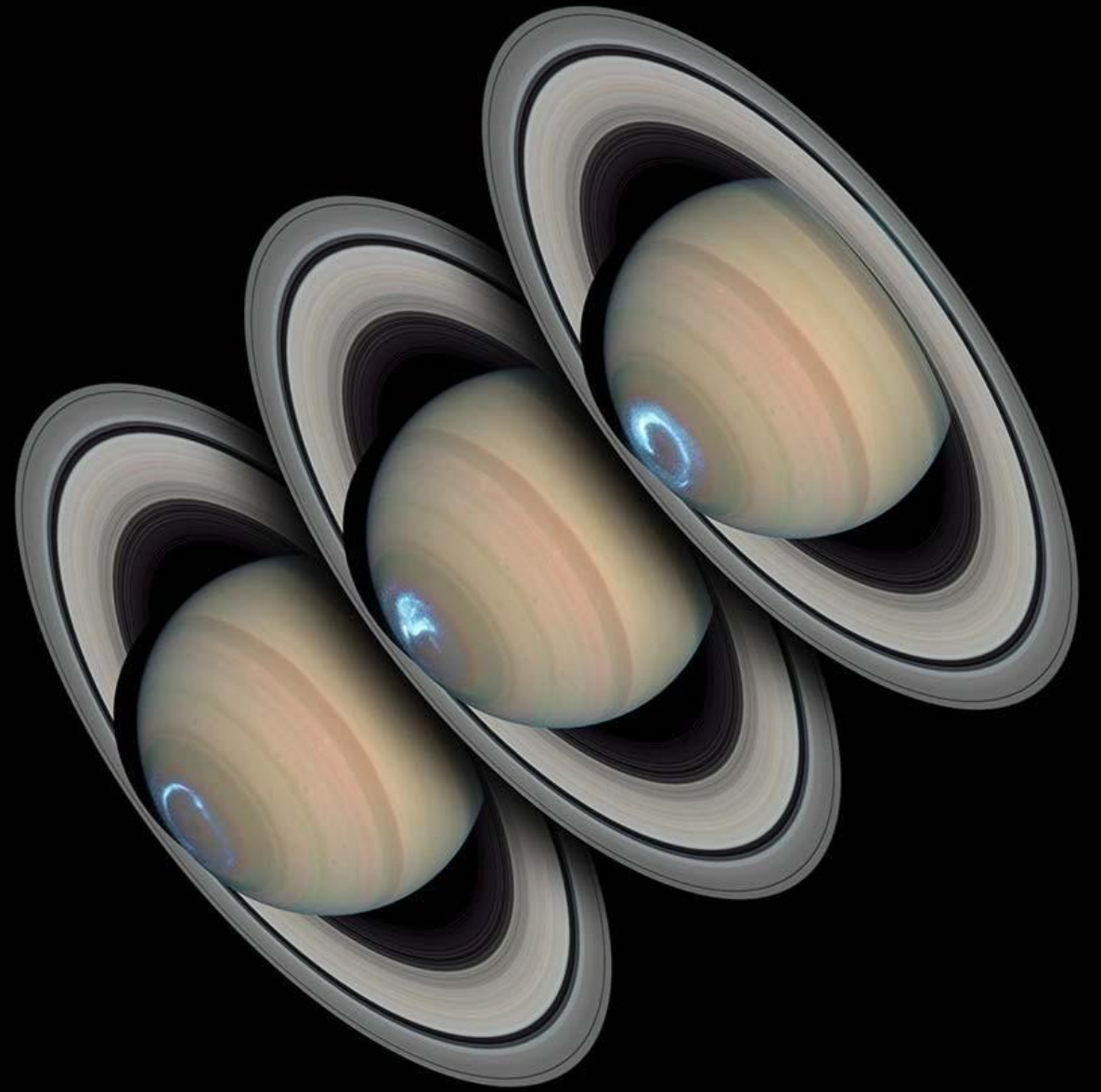
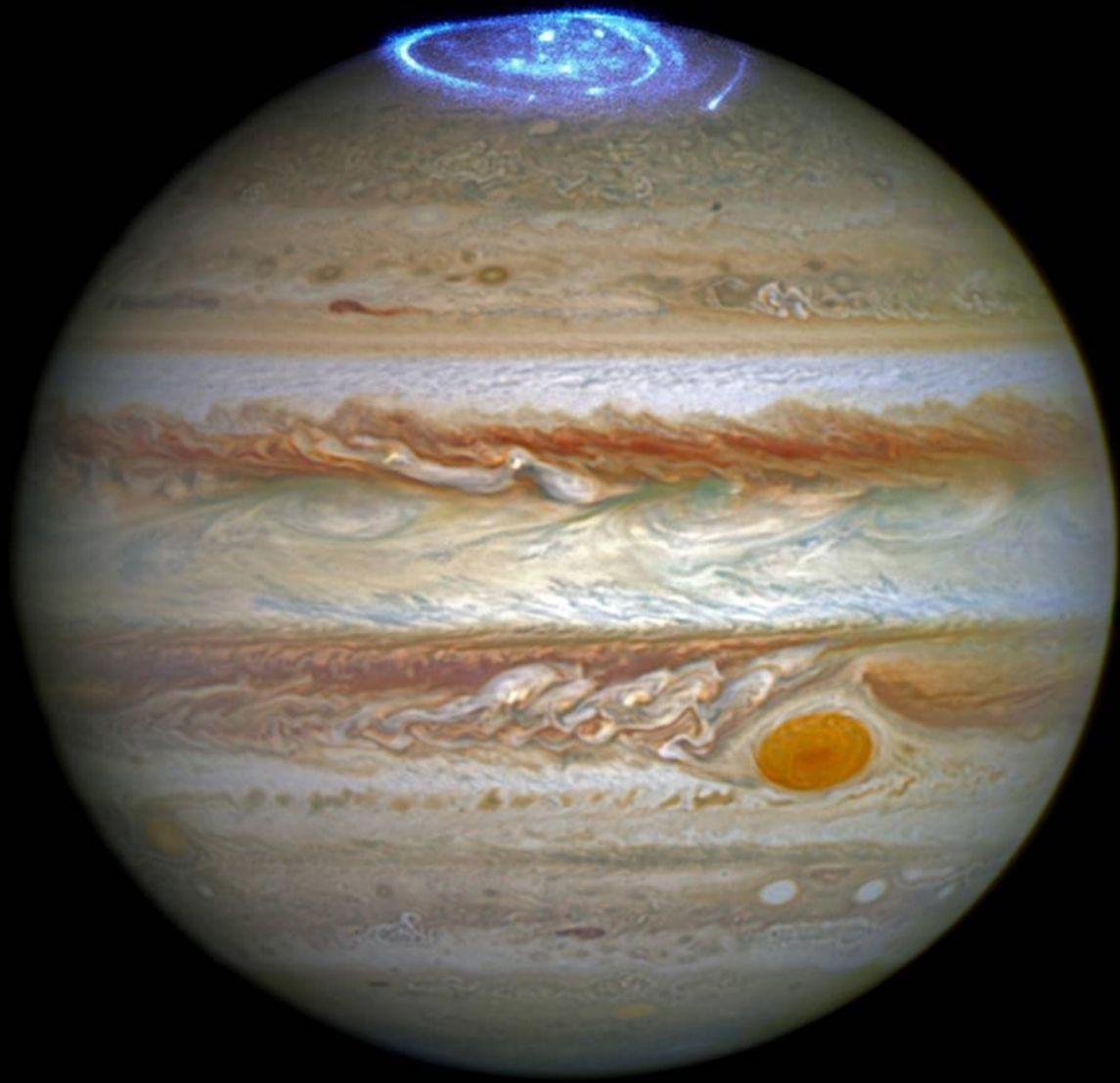
Animation from NASA/Goddard Space Flight Center Conceptual Image Lab: <https://svs.gsfc.nasa.gov/>

Auroral Oval Over Antarctica September 11,

A Weather
Analogy:
Precipitation



Composite Image: UltraViolet-emitting auroral oval as seen from NASA's IMAGE satellite overlaid on NASA's Blue Marble image.



<https://www.nasa.gov/feature/goddard/2016/hubble-captures-vivid-auroras-in-jupiter-s-atmosphere>

<https://solarsystem.nasa.gov/resources/1236/rings-auroras>

Space-Weather Effects

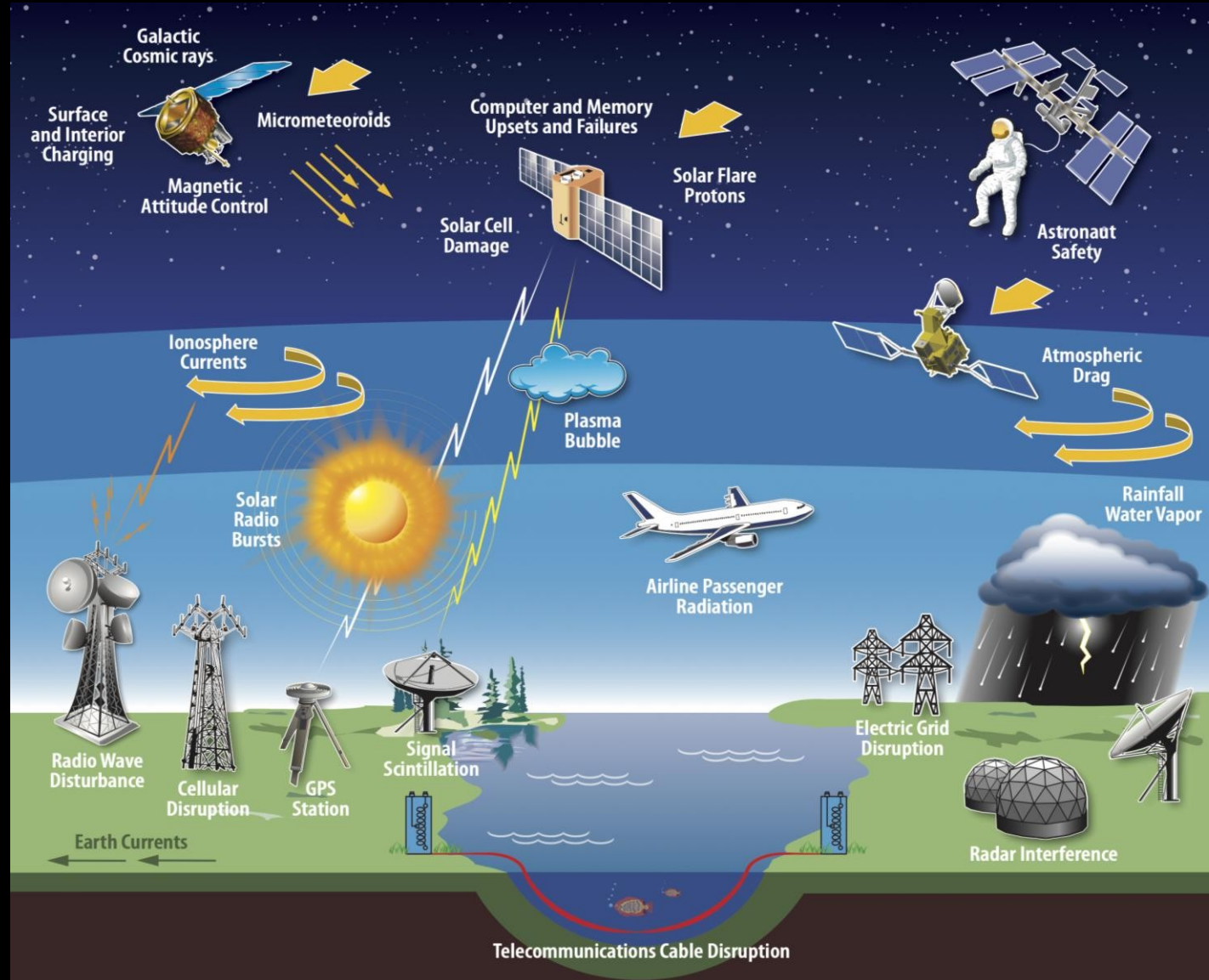


Image from NASA/Goddard Space Flight Center Conceptual Image Lab: <https://svs.gsfc.nasa.gov/>

This Just In!!

(well sort of)



From <https://www.swpc.noaa.gov/news/geomagnetic-storm-conditions-likely-2-3-february-2022>

February 3, 2022

SpaceX launches 49 Starlink satellites

February 4, 2022

A Minor Geomagnetic Storm Begins

Summary

- The Sun is a Dynamic Star.
- Sunspots are cooler than their surroundings.
- The Sun has an activity cycle of approximately eleven years.
- During the maximum of a cycle, the Sun produces more spots, and is likely to produce space-weather events...but can happen at any time.
- Space-weather events can produce effects at Earth and at any planet in the solar system with or without a magnetic field.
- Earth's magnetic field and atmosphere protects Earth from some of the most damaging effects.
- Aurorae happen when Earth's atmospheric particles, mostly electrons, are energized by magnetic reconnection and precipitate back down into the lower atmosphere...energized by magnetic reconnection.
- Always check the (space) weather report.

Two Solar Eclipses over the United States



Image Used from a Presentation by Dr. Angela Speck and with permission from Mich

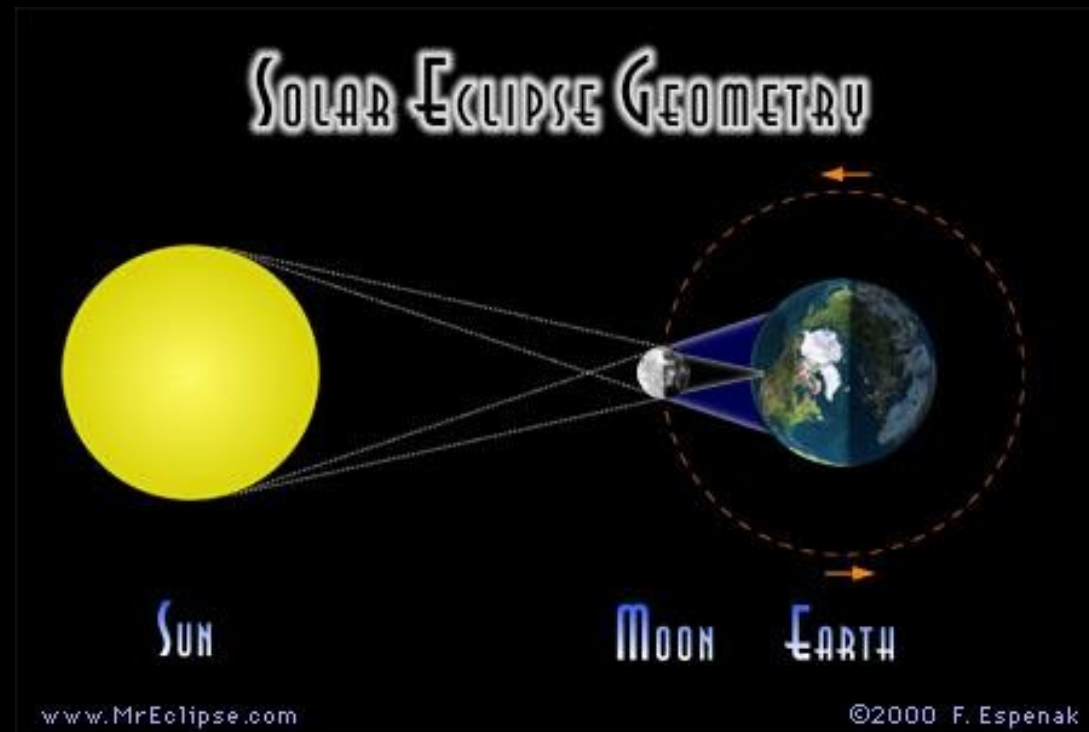
What is an Eclipse?

An eclipse happens when one object blocks the light of another



www.MrEclipse.com

©1999 F. Espenak



www.MrEclipse.com

©2000 F. Espenak

Images Used With Permission from Fred Espenak

Annular: from Annulus Meaning Ring

space.rice.edu/eclipse/
reiff@rice.edu

ANNULAR ECLIPSE
October 14, 2023

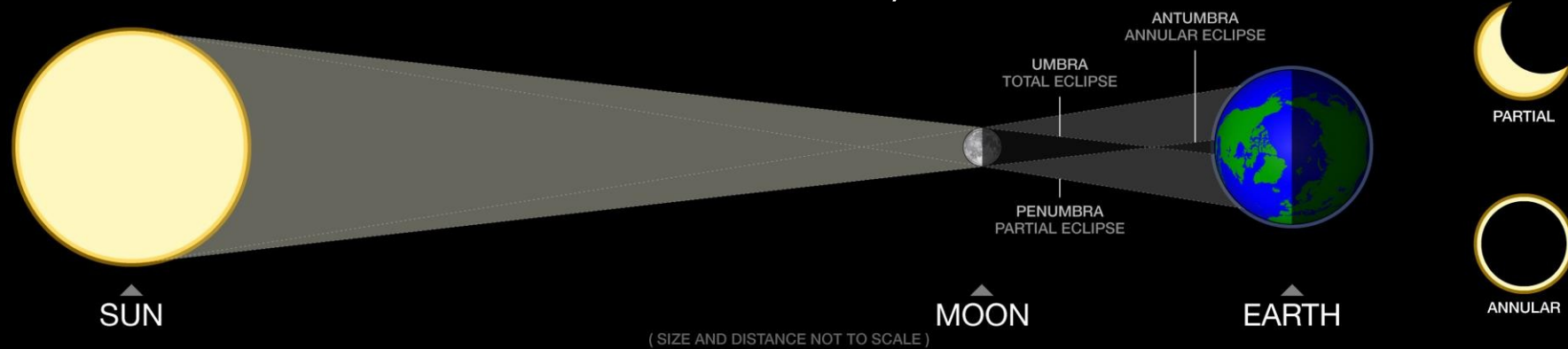


Diagram source:

https://space.rice.edu/eclipse/eclipse_graphics.html



An Annular Eclipse is a Partial
Eclipse with Good Press

Image Source: NASA/Bill Dunford

Published: October 12, 2022

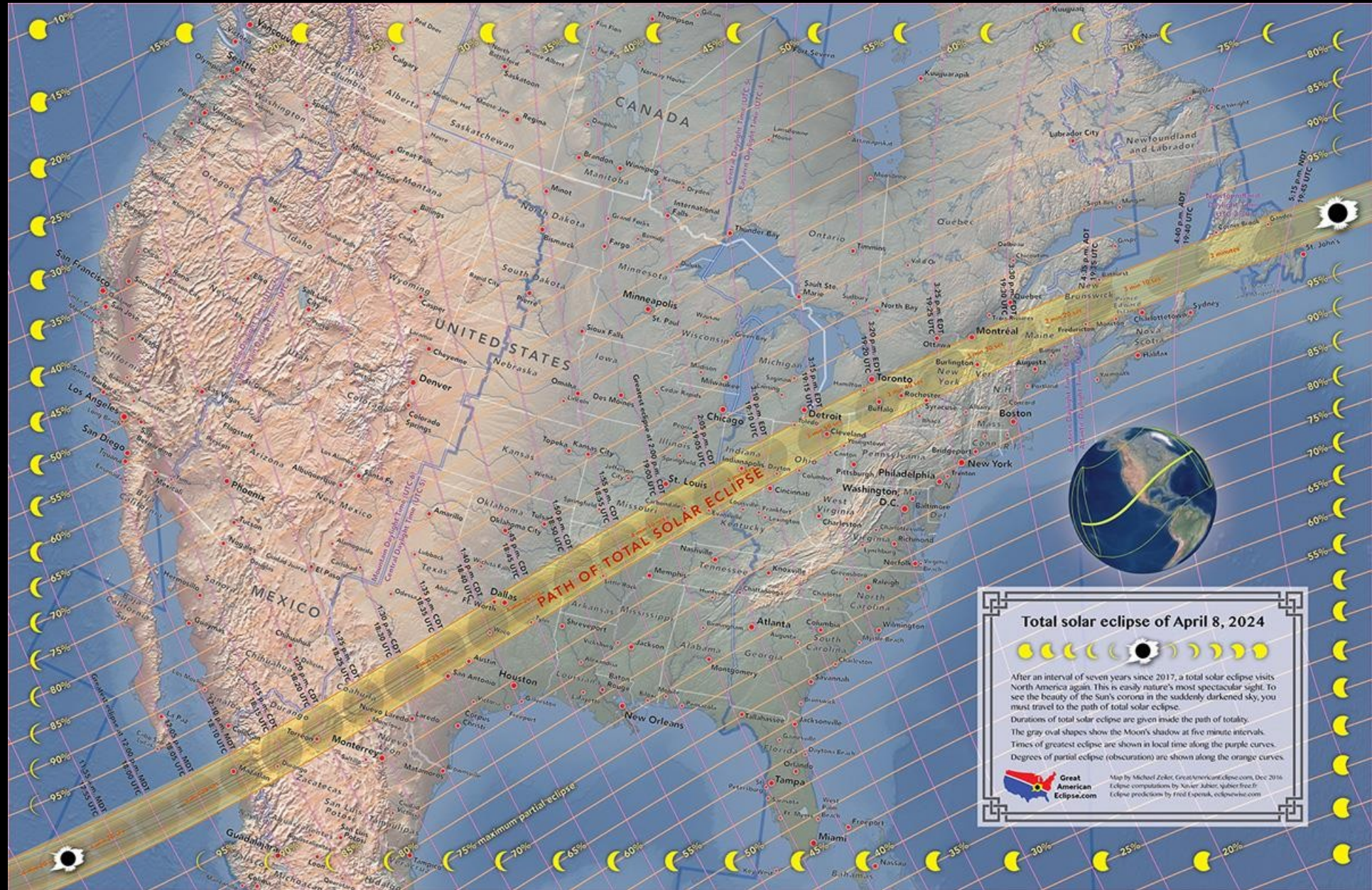
Historical Date: May 20, 2012

An annular solar eclipse photographed on May 20, 2012

From: https://solarsystem.nasa.gov/resources/2773/may-20-2012-annular-eclipse/?annular_eclipse



From: <https://solarsystem.nasa.gov/eclipses/2023/oct-14-annular/where-when>
The annular solar eclipse path crosses the United States southeast from the Pacific Coast of Oregon, exiting the Gulf of Mexico near Texas. Image Credit: ©2021 Great American Eclipse, LLC, Used with Permission from Michael Zeiler



From: <https://solarsystem.nasa.gov/eclipses/2024/apr-8-total/where-when/>
 The total solar eclipse path crosses from Mexico, through the United States from Texas to Maine, and through Canada. Image Credit: ©2021 Great American Eclipse, LLC, Used with Permission from Michael Zeiler

What You Can See: Partial Eclipse

The entire United States will see a partial eclipse.



These images of the partial phases of the 2017 total eclipse were taken by
Dr. Alphonse Sterling, NASA MSFC – Used with Permission

Maximum Eclipse at Tellico Village on April 8, 2024, 15:07 EST



The End

A total solar eclipse is shown against a black background. The sun's corona is visible as a bright, glowing ring around the dark, circular silhouette of the moon. The text "Questions??" is written in white, serif font across the center of the dark circle.

Questions??

Rob Lucas, with Jay Pasachoff's 2013 Eclipse Expedition

Image Used With Permission